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Railway Brakes

An important feature of the British Transport Commission plan for modernisation of the railways, announced more than a year ago, was the decision to equip all freight vehicles in this country with continuous automatic brakes. This step was long overdue, but since the original announcement there has naturally been considerable speculation as to which type of brake would be adopted. The vacuum is already in use on the great majority of steam-hauled passenger trains, and many freight vehicles used in priority service, such as fish, Cornish broccoli, meat, and so on are fitted with the same brake. At first sight there would seem to be obvious advantages in continuing with the vacuum in the general introduction of continuous brakes on all freight trains. No further equipment would be needed on the large number of general utility locomotives now in commission ; operating and maintenance staffs would be generally familiar with the apparatus, and on this account the recent announcement by the British Transport Commission that adoption of the vacuum brake had been recommended would cause no surprise. If the work now envisaged was merely an extension of that already done the B.T.C. recommendation could be tolerated, even so with some tinges of regret. But use of the continuous brake is now to be extended to the heavier grades of freight service, on trains at present loading up to 70 wagons, or more ; and quite apart from length of train, the application of brake power to wagons in the empty and loaded condition is involved. Freight vehicles at present equipped with the vacuum brake are run in service where the paying load is small in relation to the tare weight of the wagon, but in heavy mineral duty the loaded weight is nearly three times the empty. Starting from this point, the more one considers the recommendation to use the vacuum brake, the more disconcerting it appears.

In using the vacuum brake one must be prepared to legislate for a considerable drop in vacuum in the train pipe. With ejectors at present in standard use, a vacuum of 21 in. on the locomotive is often no more than 18 in. at the end of a 40-wagon train—indeed a drop to 17 in. is permitted on many of the fully-fitted freight trains running in the country today. This, in itself, represents a considerable loss of brake power at the rear end; but if present standards of maintenance on priority freight stock permit of such a drop, what is to be expected on the mineral wagons of the future, inevitably subject to far rougher usage?. Many coal trains are today made up to 70 wagons; to cut down the length of trains would mean duplicating many of the services, and the reduction in line occupation resulting from higher speed would be nullified to some extent from there being more trains —quite apart from the need to provide additional locomotives, and crews. And yet if a drop in vacuum from 21 to 17 in. occurs on a 40 to 45-wagon express goods train, what is to happen on a 70-wagon coal train? Maintenance of the brake gear and hose connections is not likely to be better on mineral stock subjected to the commonest of common-user duty; moreover while the use of steam locomotives continues, any loss in boiler pressure, which is unhappily frequent today with the poor quality of coal available, results in a deterioration of the performance of ejectors, and the resulting loss in vacuum could easily result in brakes leaking on and stalling of the train. With the compressed air brake no difficulty is experienced in maintaining brake pipe pressure on trains of 100 wagons, or more.

There is another factor that can have a very serious effect upon the performance of the vacuum brake. Unless the most frequent and assiduous care is taken in adjustments of the rigging, wear on the brake blocks gives rise to considerably increased strokes on the brake cylinders; and while with the air brake this does not result in a serious loss of pressure on the piston, with the vacuum already down to no more than 17 in. at the rear end the loss of vacuum is such that with ½ in. block wear the brake cylinder effort is less than half the optimum designed value for the vehicle. This, of course has the effect of considerably lengthening the stopping distance. The ill effect could be lessened by the use of certain refinements, though these would, of course, increase the cost of the installation, and still not bring the vacuum brake up to the standards of performance attainable with the air brake. In reviewing the decision of the British Transport Commission to recommend to the Minister the adoption of the vacuum brake one cannot help feeling that the difficulties of the change-over period have been allowed to overshadow the unquestionable advantages to be derived from use of the air brake. It is not as though the vacuum can ever be completely standard in this country. The air brake is used throughout the great electrified system of the Southern Region, and on multiple unit electric trains elsewhere, while on all new main line diesel-electric and electric locomotives limitation of space beneath the frames precludes the use of the vacuum brake on the locomotive itself ; the air brake must be used, with consequent duplication and complexity of controls to enable such air-braked locomotives to work vacuum braked trains. While the bulk of the British Transport Commission plan looks boldly to the future, the whole operating system of the railways is in danger of being hamstrung for-ever-and-a-day by the inherent limitations of the vacuum brake.

Flight Speed Measurement

The air speed record of the Fairey Delta 2 was the occasion for the first use in Great Britain of equipment to measure accurately the speeds of aircraft at great heights. The Federation Aeronautique Internationale require an accuracy of 0·25%, but 0·1% is achieved by the equipment developed by R.A.E., Farnborough. The base line of the course, 15·5 km long, was laid out by conventional survey methods, and concrete pillars set at each end at equal altitudes. On each pillar was mounted a camera set to swing in a vertical plane across the course, since the flight might not be directly above the base line, the pivots of the two cameras being set co-axial by means of telescopes fitting within the journals. Each camera had a reflecting optical system of 200 cm focal length, and subsidiary systems marked hair lines on each plate defining the axis of the camera: that the two cameras lay in parallel planes was established by photographing the stars at night. Mounted on each camera and swinging in a plane including the camera axis and the course was a telescope with which the aircraft, initially found by its condensation trail or a trail of smoke, was tracked: as the telescopes at the start and finish of the course became parallel to their cameras, they started and stopped electronic chronographs and exposed their respective cameras. This tracking was a highly exacting task, and only on the seventh attempt did the aircraft appear on all four exposures. The Ericsson chronographs counted micro-seconds up to 1000 seconds, presenting the total on six Dekatrons: each chronograph was controlled by a quartz crystal of 20 kc frequency, and the difference between the times recorded on each never exceeded 1 millisecond. The photographic plates showed how far from the boundary of the course the aircraft was at the instant of starting or stopping the time count; since focal plane shutters were used, a correction for their time of travel was necessary, and this was made possible by a light source, flashing at 100 c/s, within the camera. A greater difficulty was posed by the requirement that the aircraft must not descend more than 100 m., during each run, below its height 7·5 km. before the start, and its height at this stage must be the same within 100 m. for out and return runs. The static vent had to be calibrated for Mach Numbers up to 1·8 by flying past a "Venom", carrying a calibrated altimeter, which had a speed of only ·75M. The marked change in position error at M=1 resulted in a flick of the altimeter that was the pilot's chief indication of commencing supersonic flight. The altitude, indicated airspeed, and temperature of the instruments were continuously recorded, and the time of the record attempts inferred from the a.s.i. trace. Because of the difficulty of maintaining height accurately, the aircraft was allowed to rise slightly along the course.

First Electric Train Equipped with Germanium Rectifier

At Fenchurch Street station last week we inspected the first electric train to be fitted, experimentally, with a germanium rectifier for converting 50 c/s alternating current from overhead wires to direct current for the traction motors. After having completed its initial trials on the Lancaster, Morecambe and Heysham line the train recently started trials on the Eastern Region line between Fenchurch Street and Bow Junction. This line is at present electrified at 1500 V, d.c. and the trial runs are therefore made from about midnight to 3 a.m. when a.c. supply at 6·6 KV can be substituted for d.c. The germanium rectifier, which was described briefly and illustrated in our issue of January 13th. last, page 53, is a forced-air-cooled equipment of 750 kW capacity. It is built up of racks of hermetically sealed 1 kW germanium rectifier cells connected for full-wave rectification. The overall efficiency is about 97 per cent and remains high down to about 10 per cent of full load.

LITERATURE

Principles of Helicopter Engineering. By J. SHAPIRO. London: Temple Press, Ltd., Bowling Green Lane, E.C.1. Price 55s.

Principles of Helicopter Engineering by Jacob Shapiro represents an important contribution to helicopter literature and is the first really complete treatment of the subject in this country.

Although primarily intended for practising engineers of the industry, the book is so arranged as to be ideal for students and will be welcomed by many technically minded people whose acquaintance with the subject is only slight.

The author assumes the reader to have a basic knowledge of fluid mechanics and a working knowledge of applied mathematics; familiarity with the normal terminology of the subject is not a necessary prerequisite for the student as the author introduces the technical terms and explains them as they appear. A useful glossary of terms is appended.

In introducing his subject, Shapiro represents the basic concept of the "actuator disc," a concept which arose originally in the consideration of ships' propellers. On this basis and with the application of the fundamental laws of streamline flow, simple efficiency parameters are obtained for a practical rotor. Air flow patterns, studied in conjunction with the experimental results of many investigators in this field, are discussed and the results compared with those postulated by normal aerodynamic theory. In this manner, consideration of streamline flow is modified to a practical application of general flow and more advanced treatments of three-dimensional flow analysis follow.

In a section dealing with performance analysis a simple blade elemental theory is derived and presented, the accent being, in the modern manner, on the dimensionless parameters for performance evaluation.

The usual elementary treatments of aerodynamics, happily, are not present in this work and the author draws freely on the modern literature of the subject. It is unusual to find such a lucid presentation of aerodynamic theory in a book intended for practical application.

Propulsion systems, utilising piston engines, gas turbines, pressure-jet systems and tip motor systems are discussed in useful detail in so far as they are likely to influence the design. A very important section deals with the application of performance analysis to some specific design problems and the examples given provide valuable guides for a designer.

Rotor blade dynamics are examined in great detail and the mathematical treatment thereof is noteworthy. The mechanics and dynamics of both rigid and flexible blades are analysed and lead to the investigation of rotor forces and the derivatives of rotor systems. The latter systems, of course, are very fully treated and particular emphasis and careful analysis is given to the subject of rotor vibrations.

In a chapter headed "The Mechanics of Helicopter Flight" will be found a detailed treatment of the factors governing the control and stability of a helicopter equipped with various rotor systems.

Following the presentation of the, in places, very theoretical aspects of helicopter engineering, the heading "Helicopter Projects" introduces a sound and comprehensive discussion of the practical side of the design requirements and is profusely illustrated with examples of current helicopter designs.

The 350 illustrations included supplement the text to a useful degree, in particular, the graphs presented remove much of the labour usually associated with design problems and no doubt much of the information contained therein has been communicated by the leading engineers of the helicopter industry.

Analysis of Structures. By M. SMOLIRA. Concrete Publications, Ltd., 14, Dartmouth Street, London, S.W.1. Price 18s.

THE main title of this volume is apt to mislead a prospective reader as to the exact scope of the material presented. The more detailed sub-title does, however, explain more precisely its contents. Deformation method, as it is named by the author, is applicable to all structures composed of rigidly jointed members. In its essence it relies on finding, first, the expressions for the slopes at the joints in terms of the unknown end moments and displacements at the end of the members, and, secondly, writing down continuity equations for each joint. A system of equations is thus obtained containing the moments at the joints and their displacements as the unknowns. In this respect the approach and the formulæ obtained for continuous beams are identical with the Clapeyron's three-moment theorem. The book presents the application of this basic principle to continuous beams, single and multiple-portal frames with straight or curved members and numerous other selected examples of frames, culminating in the solution of complex Vierendeel trusses. In the final chapter the use of the reciprocal theorem for the determination of influence lines is illustrated. A considerable amount of work must have been put in by the author on the numerical solution of the examples given. For brevity obviously a large part of the computations is omitted and perhaps the reader should be warned that between the point of writing down the continuity equations, containing anything up to eleven variables, and the solution of these, a considerable amount of labour is involved.

The author obviously relies on the reader's reasonable knowledge of the general theory of structures. In the opinion of the reviewer it would have been of advantage not to assume the knowledge of the slope formulæ and to start the derivation, say, from the elementary beam equation. This would only increase the volume by two or three pages and would make the book more easily comprehensible to a wider circle of readers—who, indeed, may find some difficulty in finding some of the basic expressions assumed in standard texts. (This especially applies to the formulæ given for curved members.) In other respects the presentation is clear and can be easily followed. The printing is good, though it is a pity that, for no apparent reason, some equations are presented in standard type, while others are photographically reproduced from the manuscript.

In assessing the power and usefulness of the method it is difficult to be entirely unbiased by personal preferences. The method most likely to give a rapid result in an analysis is dependent on the nature of the structure concerned and on the familiarity of the designer with it. Some generalisations perhaps may be made. Application of the deformation method never reduces the number of the variables below that of the number of redundancies of the structure. In fact, for a singly redundant portal frame three simultaneous equations are obtained in place of the usual one. In this respect the deformation method, though using the same formulæ and similar principles to the well-known slope-deflection method, is less favourable. The latter presents not the moments, but the slopes as variables and often has the merit of reducing the number of simultaneous equations to be solved below that of the number of redundancies.

As the author rightly points out, it is essential for the designer to visualise the deflected form of the structure in order to be able to write down the deformation equations correctly. This presents to some a difficulty—which the use of strain energy methods neatly avoids. On the credit side, however, it should be pointed out that the equations resulting from the deformation method appear often to be better "conditioned" than those given by the use of the strain energy principle. The fact that the variables are the moments occurring at the joints is another considerable advantage. The final result, which, in general, consists of determining the bending moment diagram, is thus immediately obtained, obviating some simple, but often tedious, calculations necessary with other methods.

The Elements of Industrial Radiography. By S. V. RAINEY and H. W. HOGBEN, M.B.E., B.Sc. (Eng.). The Association of Engineering and Shipbuilding Draughtsmen, Onslow Hall, Little Green, Richmond, Surrey. Price 3s.

THIS pamphlet, which is well illustrated, discusses the nature and properties of X-rays and gamma-rays and goes on to deal with X-rays and their production, and the construction of generators. Various theoretical considerations including tube current, target film distance, geometry and definition, radiographic density, and sensitivity, &c., are briefly examined, followed by notes upon practical aspects, the darkroom, and the problems of interpretation. Gamma-ray sources and containers for radioactive isotopes are discussed and attention is given, as for X-rays, to various theoretical considerations and a number of practical aspects. Pointers towards the reasons for specifying radiographic examination are included under the heading general considerations, and the final paragraph is concerned with questions relating to safety precautions.

Brazing. London: British Welding Research Association, 29, Park Crescent, W.1. Price 5s.

THIS is the first of a series of booklets being produced by the British Welding Research Association dealing with welding processes in industry, and it was prepared by Mr. E. B. G. Trehearne. It is designed to assist designers, production engineers and managers by giving the potentialities, methods, advantages and disadvantages and design considerations of the brazing process. The book first describes the fundamentals and advantages of brazing and then goes on to deal in detail with the various heating methods, filler metals, fluxes, treatment of parts before and after brazing, design of brazed joints, and new materials. A number of clear photographs and drawings are used wherever necessary to amplify the descriptive matter.

Oil Flow and Film Extent in Complete Journal Bearings

By J. A. COLE, M.Sc. A.M.I.Mech.E.,* and C. J. HUGHES†

No. II—(*Continued from page 258, March 16th*)

This paper was read before the Institution of Mechanical Engineers on February 10th and is here abstracted.

In 360 deg. journal-bearing theory, the load-carrying film is assumed to be partial as a result of cavitation in the diverging outlet film, but the friction producing film is taken as complete. The effect of oil inlet conditions on film extent and the state of affairs prevailing in the cavitated film have been matters for speculation. A method has been developed for photographing the oil film in glass bearings of standard clearance ratio (0·001 and 0·002) and the results of a qualitative and quantitative examination of film extent are described. The measured oil outflow rates are analysed into the hydrodynamic and supply-pressure-induced components, and explanations for an apparent deficit in the former are discussed.

Quantitative Examination of Film Extent for Single Oil Hole Bearings

Photographs of the inlet and outlet films and measurements of oil flow rates and temperatures were recorded for bearings of three width/diameter ratios, nominally ½, 1, and 1½, and clearance ratio nominally 0·001. The single oil hole was opposite the load. Four values, each of load, speed and oil supply pressure, were used. To compare the observed film extent with the theoretical extent of the pressure film the angular positions relative to the oil inlet of the beginning and end of the full-width film were measured on the photographs. In Fig. 9 these angular positions are plotted in terms of Sommerfeld number (based on mean oil outlet temperature) for the three bearing widths, the continuous full-width film being represented by shading. The dotted theoretical curves are derived from Cameron and Wood (1949).

Considering film rupture first, Fig. 9 shows that at Sommerfeld numbers near and above unity the outlet film is complete, while at lower values the position of outlet film breakdown falls fairly close to the theoretical curve. Change of oil supply pressure has little effect. For the two narrower bearings film breakdown is later than the theoretical position by an average angle of 25 deg.

The accuracy of these results may be affected by a number of factors. The maximum possible error in the determination of angles on the photographs varies from ±5 deg. at the centre to ±15 deg. at the angular extremes, and would explain some of the scatter of the observations, but not the deviation from theory. Considering Sommerfeld numbers, the experimental values require multiplication by at least 4 to make the points fall on the theoretical curve. The likely errors are in the estimation of viscosity, load and clearance. The use of outlet temperature may be expected to lead to an overestimate of the representative viscosity and the neglect of supply pressure to an underestimate of the effective load; correction of these factors reduces rather than increases Sommerfeld number. Larger determination of clearance from separate measurements of bush and journal, but even these cannot account for the deviation.

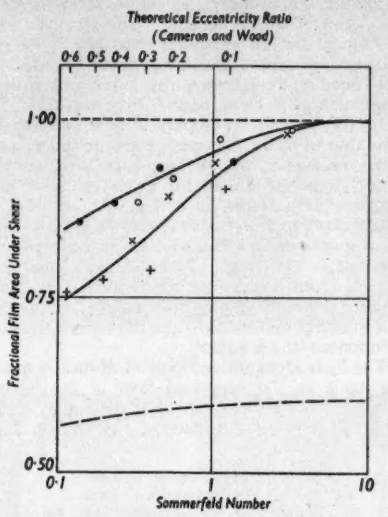
The beginning of the oil film is more difficult to define. Here it has been taken as the position at which the inlet film attains full bearing width, errors, up to 12½ per cent, are possible in the although this neglects the introductory spreading portion.

At the highest values of the Sommerfeld number the inlet film, like the outlet film, is complete. As the Sommerfeld number is decreased the inlet film ruptures before the outlet film, forming cavities as already described, and further reduction produces the characteristic inlet pattern. The full-width film now starts generally later than theoretically predicted, the maximum delay being about 70 deg. with the smallest supply pressure and clearance used. The results show more scatter than those for film breakdown, but confirm the earlier qualitative observations of the effect of supply pressure and clearance.

Estimates have been made from a number of the photographs of the fraction of the bearing surface area with an oil film present under shear, and these appear in Fig. 10, which relates to a width/diameter ratio of 1·1. The film area varies from 75 to 100 per cent of the total bearing surface area, the lower figure referring to the minimum feed pressure and maximum operating eccentricity.

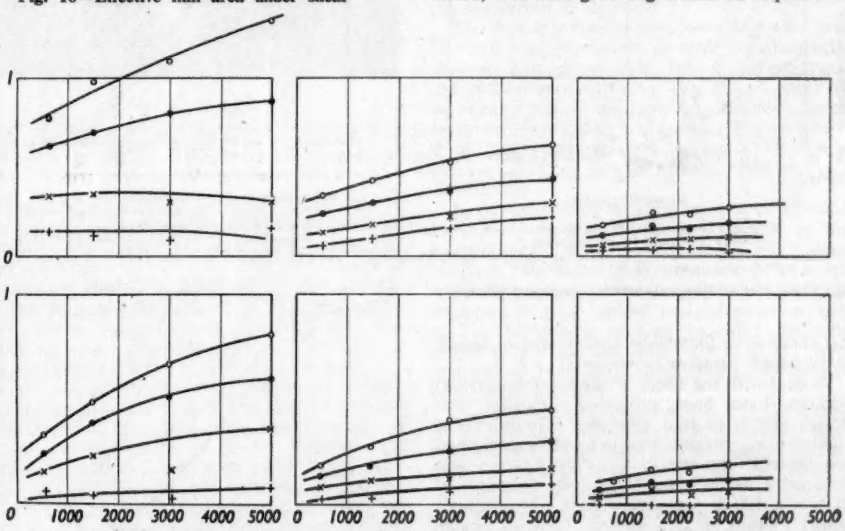
Oil Flow Rates for Bearings with Single-Hole Oil Entry

The oil flow rates corresponding to the film extent photographs for bearings with a single-hole oil entry opposite the load have been measured. With a single oil hole, oil flow is small at the nominal clearance ratio (0·001) tested, and inlet grooving would be required to



Width/diameter, 1·1. Clearance ratio, 0·0012.
○ Supply pressure, 23 lb per square inch; speed, 1500 r.p.m.
● Supply pressure, 23 lb per square inch; speed, 500 r.p.m.
× Supply pressure, 0·5 lb per square inch; speed, 1500 r.p.m.
+ Supply pressure, 0·5 lb per square inch; speed, 500 r.p.m.
– – – – – – – Complete 2π film.
— — — — — 0 to π+α pressure film.

Fig. 10—Effective film area under shear

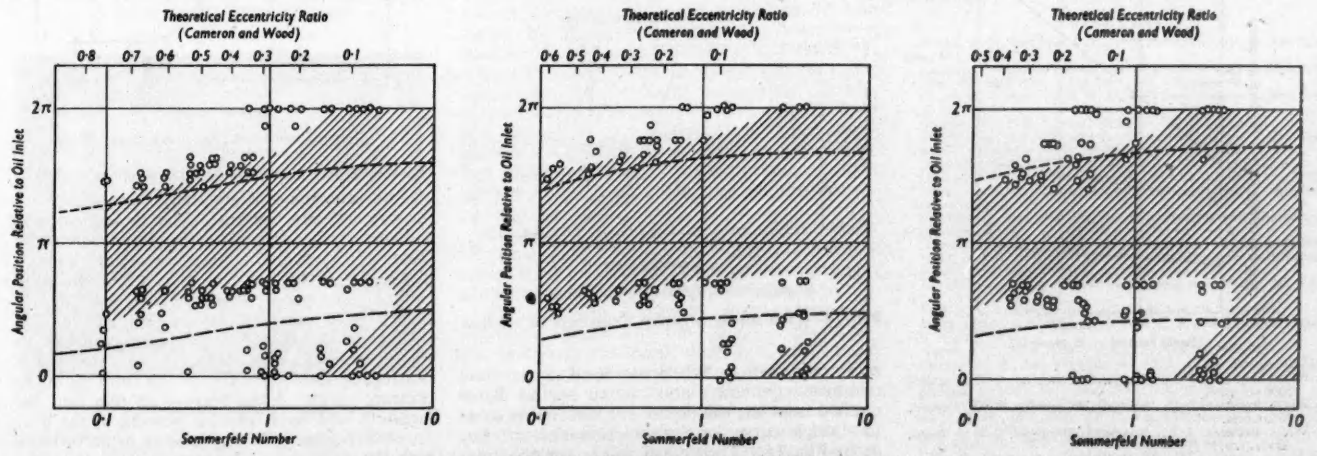


(*a*) Width/diameter, 0·6; clearance ratio, 0·0016.
○ Nominal loading, 100 lb per square inch.
+ Nominal loading, 10 lb per square inch.

(*b*) Width/diameter, 1·1; clearance ratio, 0·0012.
● Nominal loading, 60 lb per square inch.

(*c*) Width/diameter, 1·7. clearance ratio, 0·0013.
× Nominal loading, 30 lb per square inch.
Upper set: supply pressure, 23 lb per square inch; Lower set: supply pressure, 6 lb per square inch.

Fig. 11—Oil flow rates in terms of load, speed and supply pressure



– – – – – – – – – – Theoretical film end. — — — — Theoretical film start.

Fig. 9—Angular extent of full-width film

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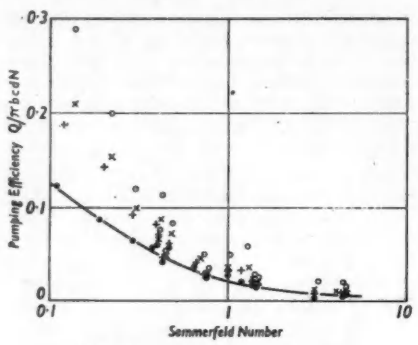
augment the flow for many applications. An indication of the effects of load, speed and supply pressure on the flow for the three bearing widths is given by the set of results in Fig. 11. Load has more effect than speed, as the increased pumping effect of higher speed is offset by the reduction of operating eccentricity. Since flow is low at small eccentricity ratios, a high-speed bearing normally requires high supply pressures, a large clearance and/or inlet grooving to ensure adequate cooling oil flow. However, the film extent photographs suggest that the extra flow produced by high pressures and inlet grooving is discharged from the bearing before reaching the load-carrying film, so that the cooling is largely external.

Movement of the oil inlet position affects the flow and, when situated at either 90 deg. in advance or in retard of the standard position described above, the flow is diminished.

To obtain a comprehensive picture of bearing oil flow it is necessary to resort to dimensional analysis, endeavouring to correlate the effects of load, speed and supply pressure by the use of dimensionless parameters. The most satisfactory correlation of the present observations has been obtained in terms of Sommerfeld number using the flow parameter $Q/\pi bcdN$ previously discussed. The results then fall reasonably well into a series of curves for different supply pressures, increasing eccentricity leading to higher pumping efficiencies (Fig. 12). However, it will be observed

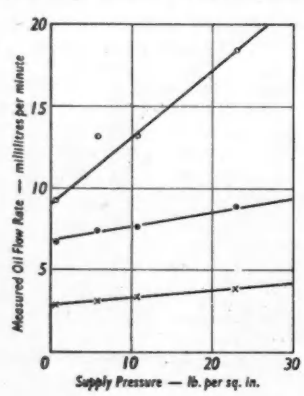


● Supply pressure, 0·5 lb per square inch.
+ Supply pressure, 6 lb. per square inch.
× Supply pressure, 11 lb per square inch
○ Supply pressure, 23 lb per square inch

Fig. 12—Total oil flow expressed as pumping efficiency

that there is an increasing scatter, due to speed, as the supply pressure is increased.

To deal with the effect of supply pressure two methods have been suggested. DuBois and Ocvirk (1953) plotted pumping efficiency as a fraction of eccentricity ratio in terms of a modified Sommerfeld number $S\times(P/p)\times(b/d)^2$ and obtained a single curve for supply pressures of 40 lb and 100 lb per square inch. The present results plotted in this manner showed similar trends, but the scatter was considerable, possibly because the ratio of maximum to minimum supply pressure was 18× that of the authors cited.



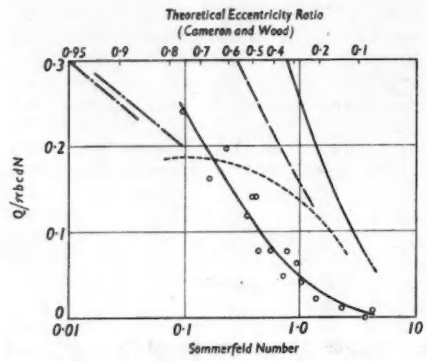
○ Width/diameter, 0·6; Sommerfeld number, 0·43; speed, 5000 r.p.m.
● Width/diameter, 1·1; Sommerfeld number, 0·45; speed, 5000 r.p.m.
× Width/diameter, 1·7; Sommerfeld number, 0·31; speed, 3000 r.p.m.

Fig. 13—Oil flow against supply pressure

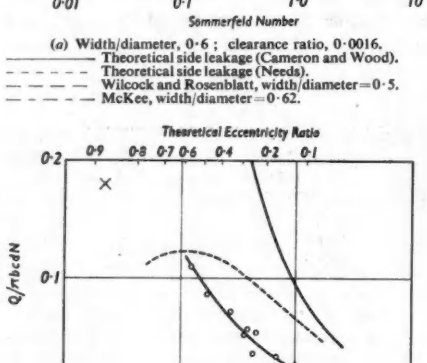
An alternative approach is to apply Barnard's empirical assumption (Barnard, 1926) that the total bearing outflow may be regarded as the sum of a zero supply pressure component, being the side leakage produced by the hydro-dynamic lubrication process, and a supply pressure component, being the lubricant flow from the clearance space under the action of the supply pressure. The theoretical implications of this procedure are not altogether satisfactory, but as the method works satisfactorily in practice its use, pending replacement by a method with a sounder logical basis, seems to be justified.

In the procedure employed here, graphs of flow rate in terms of supply pressure (corrected, when necessary, for the pressure drop in the supply line) are drawn for given values of the Sommerfeld variable, as in Fig. 13, the form of which explains Clayton's (1946) observation that the response of flow to a wide variation of supply pressure is not large. Mean straight lines are drawn, from which can be deduced the zero supply pressure or hydrodynamic component (the intercept on flow axis) and the supply pressure component (the gradient).

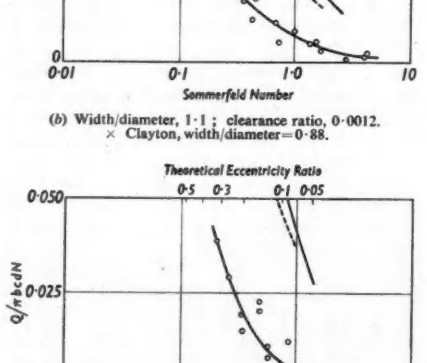
The hydrodynamic component of flow is much the same as the measured flow at the lowest supply pressure (nominally ½ lb per square inch) and is proportional to speed at a given operating



(a) Width/diameter, 0·6; clearance ratio, 0·0016.
——— Theoretical side leakage (Cameron and Wood).
– – – – – Theoretical side leakage (Needs).
— — — — Wilcock and Rosenblatt, width/diameter = 0·5.
— – — – — McKee, width/diameter = 0·62.



(b) Width/diameter, 1·1; clearance ratio, 0·0012.
× Clayton, width/diameter = 0·88.



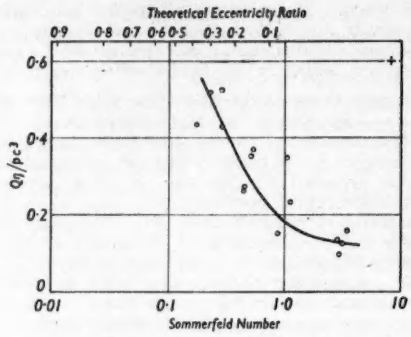
(c) Width/diameter, 1·7; clearance ratio, 0·0013.

Fig. 14—Zero supply pressure component of oil flow

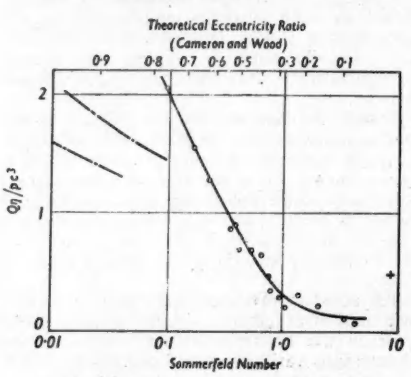
eccentricity ratio. When expressed as the flow parameter $Q/\pi bcdN$ and plotted against Sommerfeld number, the points fall reasonably close to a single curve for each width/diameter ratio, as in Fig. 14. Theoretical values for the side-leakage flow derived from Cameron and Wood are also shown and are at least three times the experimental values, the disparity increasing at high Sommerfeld numbers (or small eccentricity ratios). The experimental values, expressed as fractions of the theoretical values, vary with bearing width, and for comparable values of eccentricity ratio or of Sommerfeld number are greatest for the width/diameter ratio 1·1.

Again, the possible errors in the evaluation of flow parameter and Sommerfeld number are far too small to account for this deviation from theory, and analysis of experimental results obtained by Clayton (1946), McKee (1952), and Wilcock and Rosenblatt (1952) shows discrepancies of the same order, as indicated in Fig. 14.

In the earlier discussion of oil flow and film extent it was shown that the hydrodynamic side leakage is reduced by late commencement of the



(a) Width/diameter, 0·6; clearance ratio, 0·0016.
– – – – – McKee, width/diameter = 0·62.
\+ Dennison, concentric.



(b) Width/diameter, 1·1; clearance ratio, 0·0012.
× Clayton, width/diameter = 0·88.
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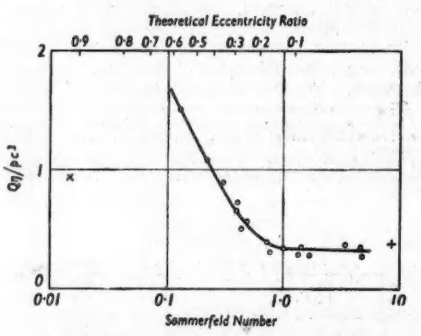


(c) Width/diameter, 1·7; clearance ratio, 0·0013.
\+ Dennison, concentric.

Fig. 15—Supply-pressure-induced component of oil flow

oil film, and this is in qualitative agreement with the present observations. The theoretical side leakage flows derived from Needs' analysis (Needs, 1934) of the 120 deg. bearing also plotted in Fig. 14, show, however, that a late film start cannot account for all of the flow discrepancy, especially at high Sommerfeld numbers.

Some of the discrepancy may be attributed to the oil meniscus which forms at each side of the bearing, permitting oil circulation from the high-pressure region of the bearing oil film into the meniscus and back into the bearing in the low-pressure region. This process is in accordance with the qualitative observations already noted of the role of the meniscus, and is quantitatively

reasonable on the basis of the relative volumes of the bearing clearance space and the two menisci. On the other hand, it would be expected that the circulation process would be considerably reduced by restricting the formation of the oil menisci. Experiments in which each side of the bearing was continuously wiped to remove the meniscus led to a flow increase of only a few per cent, although this may only indicate that the wiping process was inefficient. Centrifugal action also would be expected to reduce the size of the oil meniscus at high speeds, but no positive evidence of a speed effect has been obtained.

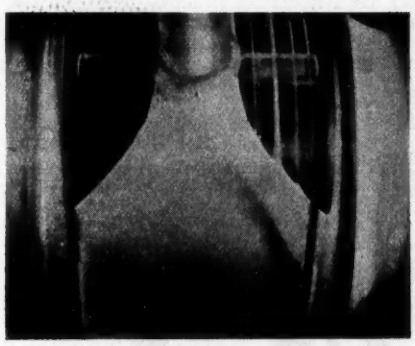
The supply-pressure-induced flows (Fig. 15) are presented as the non-dimensional parameter $Q\eta/pc^3$, the value of which represents the geometrical resistance factor of the bearing for the Poiseuille type of flow. At concentricity the factor is $\frac{1}{4}\tan^{-1}\pi d/b$, according to Dennison's theory (Dennison, 1936), which applies to a stationary bearing with a complete film. The experimental values extrapolated to concentricity fall below this.

As the bearing becomes more eccentric the clearance at the oil hole increases and the resistance to supply-pressure-induced flow drops. Since the hydrodynamic flow is speed dependent and the supply pressure flow is independent of speed, the total flow expressed as $Q/\pi bcdN$ would be expected to show the speed effect noticed in Fig. 12. With bearings employing inlet grooving systems and high oil supply pressures the supply pressure flow component will be larger relative to the hydrodynamic flow component than with the present results, and in some instances the hydrodynamic flow will be comparatively negligible.

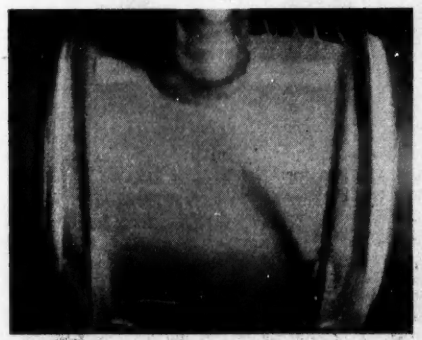
The Influence of Oil Inlet Shape

Photographs have also been taken of the film pattern for bearings of width/diameter ratio unity with three forms of oil grooving—an axial groove, a complete circumferential groove, and a relieved area. The clearance ratio was nominally 0·002.

It has been found that the axial groove does not fulfil its intended function of spreading the oil across the full inlet film width unless the supply pressure is fairly high. At pressures below approximately 16 lb per square inch the inlet film shape corresponds to that for a single oil hole as shown in Fig. 16, but the effect of clearance needs examination.



(*a*) Supply pressure, ½ lb per square inch.



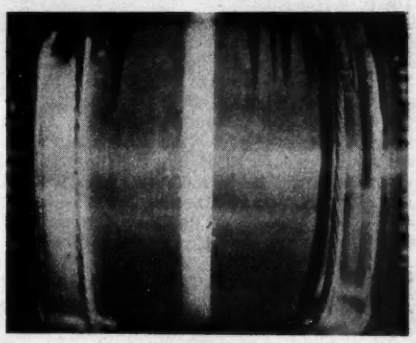
(*b*) Supply pressure, 23 lb per square inch.

Speed, 1000 r.p.m. Load, 60 lb per square inch. Width/diameter, 1. Clearance ratio, 0·002.

Fig. 16—Inlet film with axial groove

The circumferential groove also gives an incomplete film at any appreciable operating eccentricity, and even at the maximum available supply pressure of 23 lb per square inch the complete circumferential film exists only adjacent to the groove (Fig. 17). The film pattern is quite

(*a*) Inlet film.



(*b*) Outlet film.

Speed, 4000 r.p.m. Load, 60 lb per square inch. Supply pressure, 23 lb per square inch. Width/diameter, 1. Clearance ratio, 0·002.

Fig. 17—Film pattern with circumferential groove

insensitive to oil hole position. This type of grooving is not normally used in steadily loaded bearings, but it has been found useful in bearing test machines where the load, though constant in magnitude, may be applied in different directions.

The relieved area round the oil hole modifies the bearing characteristics far more than the axial or circumferential grooves. Oil flow is augmented by a factor of between 10 and 50, and the film extent is increased. Only at the highest supply pressure used does the relieved portion itself run full of oil and normally the space is filled by a churning mass of oil. However, the full-width inlet film does start rather earlier with this bush, and at low eccentricities, when the position of outlet film breakdown falls within the relieved area, cavitation is apparently suppressed.

Discussion of Results and Conclusions

The film extent results confirm the original surmise that the friction-producing film is by no means complete, and it seems likely that the discrepancy between some published friction results and theoretical calculations based on a continuous film is attributable to this cause. It is hoped to confirm this in future tests on transparent bearings by also measuring friction. However, the film-area measurements indicate that complete film calculations may overestimate friction loss by as much as 30 per cent. The effects of supply pressure and oil inlet geometry are considerable, and require investigation.

The ruptured outlet film is composed of orderly filaments of oil : none of the photographs shows evidence of oil foaming, even at the maximum surface speed (22ft per second) employed.

The full-width film-extent measurements do not agree closely with the "positive pressure" film boundary conditions used by Cameron and Wood and by Sassenfeld and Walther. The extent of the visible film is not necessarily the same as the extent of the positive-pressure region, and the full-width film criterion used neglects the widening inlet stream. The comparison between theory and experiment is also subject to the usual uncertainties regarding effective clearance and film viscosity, although the operating conditions make large errors due to temperature effects unlikely.

The position of film breakdown is later than the theoretical $\pi+\alpha$ position, and the results are fairly consistent. The implication is that the outlet film is prolonged by the existence of a shallow subatmospheric pressure loop. This would be compatible with flow continuity, provided an inflow of oil from the bearing sides occurred towards the end of the film, and this seems likely to be possible.

For the clearance used in these tests, the full-width inlet film commences later than the position of maximum film thickness, $\theta=0$, except with low speeds and high supply pressures for the narrowest bearing. However, the theoretical criterion is logical only under the idealised condition of an unlimited supply of lubricant, when pressure generation must start with film convergence. Under practical conditions, the criterion for film commencement must take into account the supply pressure and oil inlet geometry, and these may not be suitable, as here, for the formation of a full-width film until later than $\theta=0$. The effect of supply pressure for the clearances examined here is relatively small, but it increases with larger clearances. The dependence of film commencement on supply pressure, inlet form, clearance and speed, therefore requires a more comprehensive investigation.

These divergencies between theory and experiment may be partly responsible for the observations of DuBois and Ocvirk (1953) and Clayton and Jakeman (1936), that width/diameter ratio does not uniquely determine the attitude-eccentricity locus. Further investigation, using transparent bearings with film-thickness measuring equipment, is desirable.

The flow rate results have been separated into the zero supply pressure or hydrodynamic side-leakage component and the supply-pressure-induced component, since the flows appear to be linearly related to supply pressure for a given Sommerfield number and speed. The empirical flow separation method gives a consistent representation of the results for a wide range of conditioris.

In this paper only bearings under a steady load have been considered. Less is known of the hydrodynamic conditions in dynamically loaded bearings : Swift (1936–37) considered that it was not easy to visualise a systematic periodic sequence of film rupture and reformation, and in his theoretical analysis assumed that the pressure film was complete from 0 to 2π. It is intended to investigate this using glass bearings and cinephotography.

The experimental method has a wider range of application than has been described here. Combined with a suitable flow-line technique, it will be possible to investigate various forms of oil entry and the most efficient way of introducing any necessary cooling oil into a bearing. From the results obtained so far, it seems that oil flow in excess of the comparatively small amount required for hydrodynamic lubrication leaves the bearing before reaching the load-carrying region so that its cooling action within the film is limited.

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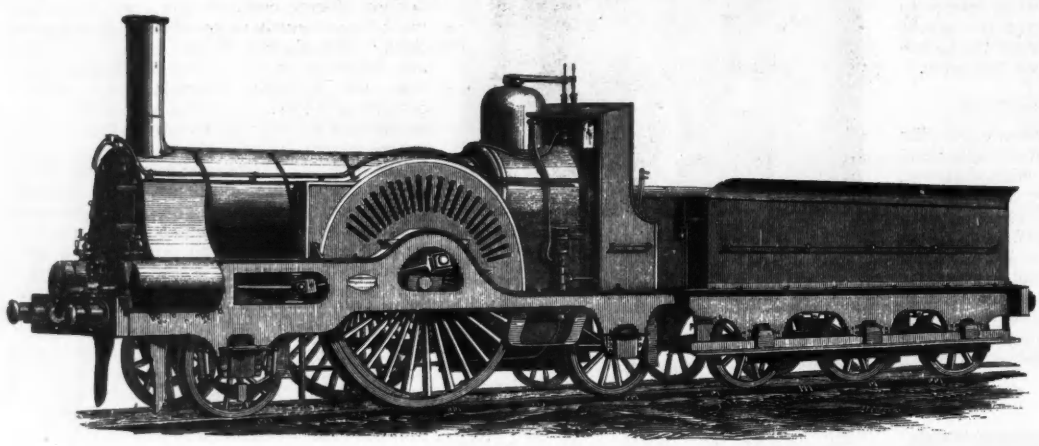
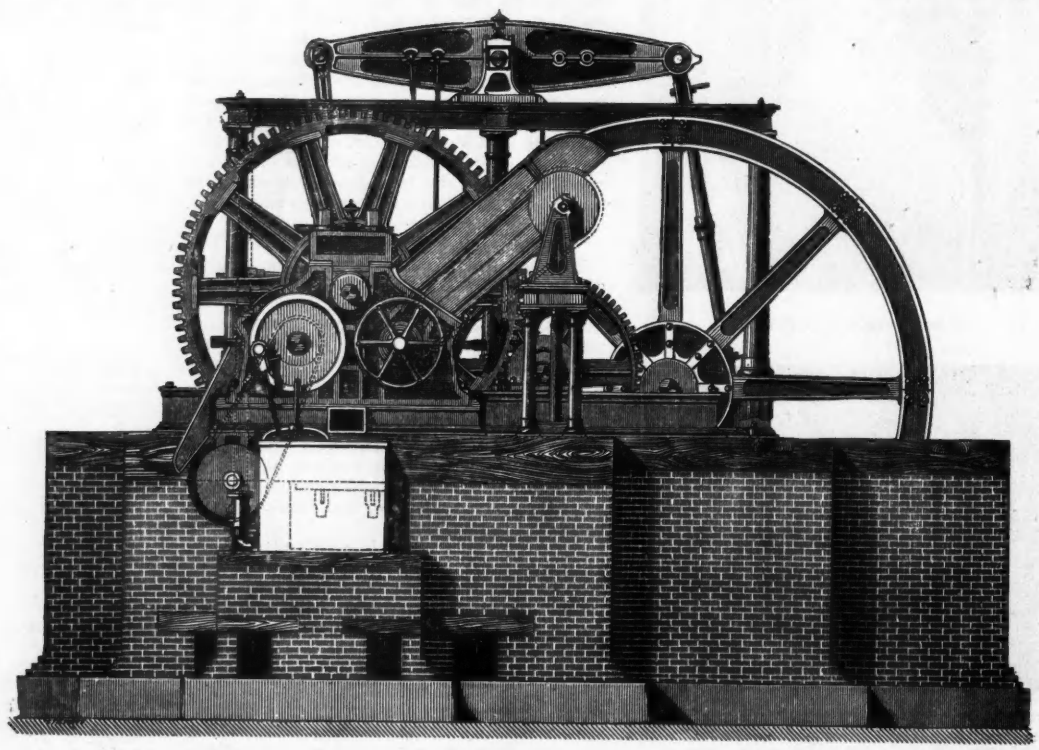
Engravings of 1862

In our issue of July 11, 1862, there was reference to a trial of steam fire engines which had taken place a few days earlier in Hyde Park. That article included an illustration of a fire engine built by Merryweather and Sons, which is reproduced here. Our first comment was that the carriage consisted of "a strong wrought iron frame of a novel form, pivotted upon a wrought iron fore carriage, to prevent straining in passing over uneven roads." Between the hind wheels, which were described as "large," there was the "upright multitubular boiler," containing a number of vertical copper tubes. The steam producing power of this boiler, it was stated, "was of a very high order, as was shown at the public trial, when the boiler (perfectly cold, not having been used for some days) was supplied with cold water from the Serpentine, and the fire lighted; in six minutes steam was heard issuing from the cocks." In just under twelve minutes the steam pressure was up to 100 lb. per sq. in. The equipment included a horizontal double-acting pump 6½in. diameter, with 15 in. stroke, the piston-rod of which was coupled direct to that of the steam engine. The description added "two stout rods connect the steam cylinder and pump together and take the whole of the strain." The engine, with its equipments, was "drawn by a pair of horses at good speed." At the trial in Hyde Park, the engine began working with a 1½ in. hose pipe, and later, as an experiment, the jet was changed to ½ in. "to show that the engine would work at a slow speed." With a 1½ in. jet water was "projected 150 ft. high and 166 ft. horizontally."



This engraving, reproduced from our issue of May 16, 1862, illustrates a "fine express locomotive" shown by Neilson and Company, of Glasgow, at the International Exhibition in London. The engine, which was built for the Caledonian Railway, had 8 ft. 2½ in. driving wheels, the leading, trailing and tender wheels being 3 ft. 8 in. diameter. In working order, the engine weighed 30 tons 13 cwt. and the wheel base of engine and tender combined was 33 ft. 8 in. The engine was described as "one of the finest examples of locomotive construction in the exhibition."

The sugar mill illustrated by this engraving was shown at the International Exhibition by Mirrlees and Tait, of Glasgow. An account of it, printed in our issue of May 16, 1862, described it as "being a specimen of the largest size in use, and capable of expressing easily 4,000 gallons of juice per hour, equivalent to, say, two tons of sugar." The mill had three rolls, each 33 in. diameter and 7 ft. long, the power being provided by a "6-columned high-pressure beam engine," the usual working pressure being 70 lb. per sq. in. The cylinder was 22 in. diameter, with a stroke of 4 ft. 6 in. "The power of the engine is transmitted," the description states, "and the speed of the rollers reduced to the required velocity by a heavy train of compound gearing, all firmly secured to a massive cast iron bed-plate on the same level as the engine."



Industrial Progress in Australia

SINCE 1915, when Australian production of iron and steel started on a large scale with the establishment of the Broken Hill Proprietary (B.H.P.) Company's works in New South Wales, South Australia has been the major source of ironstone. Indeed, until 1951 it was the only regular source. But in recent years it has ceased to be merely the State which has played a leading role in the foundation and development of the iron and steel industry. Mainly engaged in agricultural and pastoral industries before the war, it has since become of increasing importance as a producer of manufactured goods with a substantial number of steel using industries. This industrial transformation is due in large measure to the B.H.P., which either directly or in collaboration with associated companies, has been responsible for the establishment and development of a number of heavy industries. In all, the company has spent over £A9,000,000 on plant and development in South Australia during and since the war, most of it at Whyalla, the port of shipment of iron ore.

Industrial Development at Whyalla

In 1937, as the result of an agreement with the then Government of South Australia, B.H.P. undertook to establish basic units of plant in that State. Notwithstanding the absence of coking coal in South Australia, the agreement included a promise by B.H.P. to erect a blast furnace. Ability to divorce the iron-making process from the coalfields (the natural centre for iron smelting), had been made possible by B.H.P.'s advancing efficiency in the use of fuel. By 1937, blast furnace fuel economy in Australia had reached a level where the South Australian proposition could be entertained as a practical one. Normally it is an axiom of the industry that integrated iron and steel plants should be located on or close to high-grade bituminous coalfields, though there have been exceptions. B.H.P. having undertaken to build a blast furnace at Whyalla, faced the necessity of having to transport coke from its by-product coking plants on the coalfields to Whyalla. Ironstone was, of course, available locally from the Iron Monarch. On this basis an iron-making industry has been built up at Whyalla since 1941 (the year the furnace was blown-in), which to-day supplies the greater part of the Australian ferrous foundry industry with its requirements of pig iron. Since then there has been almost continuous growth of manufacturing industry, not only at Whyalla, but in and around Adelaide and at a number of other country centres. Not that the iron and steel industry has been responsible for everything that has happened since 1937; but its readiness to expand its activities in South Australia gave a fillip to industrialisation and thus opened a new phase in the State's history.

Shipbuilding

The building by B.H.P. of South Australia's first modern blast furnace was only the first of a number of projects in an expansion programme which has transformed Whyalla. In 1937 the town's population was about 1000; by 1945 the number had risen to 8000 and it is still growing, if more slowly than during its first boom period. Whyalla's dependence on coke and coal imported from New South Wales (and on water "imported" by pipeline from the Murray River, 223 miles away), obliged the locating of the blast furnace at tidewater. Since deep water was not available close in shore, it was necessary to dredge a harbour, so that raw materials for the blast furnace could be unloaded mechanically from ships into stockbins adjoining the wharf, from which the furnace could be fed. The harbour and the blast furnace were completed in record time and in May, 1941, the furnace was blown-in. It has a rated capacity of 750 tons of basic pig iron a day. Towards the end of 1939 another event of great importance for Whyalla had occurred. It was a decision by the company to build a shipbuilding yard, with facilities to turn out vessels of dead weight tonnage of up to 22,000. For many years B.H.P. had had in mind building its own ships to meet the needs of the iron and steel industry. From their inception the Newcastle Iron and Steel Works had leaned heavily on coastal shipping to transport ironstone, limestone and other basic raw materials to Newcastle, and to move steel products to markets other than New South Wales. With the establishment of an iron and steel works at Port Kembla in 1928, reliance on shipping had been further extended. Almost inevitably B.H.P. had built up its own fleet of cargo vessels after 1915, the successful operation of which had done much to assist in the efficient transport of the iron and steel industry's bulky raw materials. On a number of occasions the possibility of the company's establishing its own shipbuilding yard had been looked into, but it was not until the second half of the 1930s that the proposition became one of practical economics. The company had, of course, always had Newcastle in mind as the most suitable site for a shipbuilding project. The war introduced a note of urgency.

Australia was ill-prepared to meet a threat to its shipping resources. Its once thriving shipbuilding industry had suffered severely during the 1920s and 1930s with the result that the few local yards that had managed to survive were ill-placed to embark on a vigorous building programme. One of the earliest acts of the Commonwealth Government, following the outbreak of war, was to approach B.H.P. with a request that the company undertake, as soon as possible, the building of naval and merchant vessels in Australia. The Government's request met with a ready acceptance and in December, 1939, plans for a large shipbuilding yard were quickly drawn up. The selection of Whyalla to be the site of the shipyard was a break with previous thinking, but it fitted in with the company's desire to help build up the industrial strength of South Australia. The suitability of Whyalla for shipbuilding had mounted as work on the artificial harbour progressed. The landward end of the harbour lent itself admirably for building berths and five were built. There was, of course, no limit to the amount of land available for the necessary buildings—loft, plate and bar shop, shipwrights' department and carpenters' shop. Another factor in Whyalla's favour was its dry climate; since the work of building a ship must inevitably take place out in the open, a dry climate is of great value. Offsetting these advantages, however, was the lack of men trained in shipbuilding, and one of the most remarkable achievements of the early years was the building up of a labour force from all parts of Australia equal to the task of manning Australia's largest shipbuilding yard. It is one of the minor tragedies of the post-war period that the levels of activity achieved in those early years have been impossible to maintain because of the persistent labour shortage since 1945.

New Industries

A new "works area" thus came into being at Whyalla during the period 1938 to 1941. Until then activity had been concentrated almost entirely around the ore-loading jetty and the town had in fact spread out from that point. Thereafter the new harbour, 2 miles to the north, became the focal point of the company's industrial activity. New works included the blast-furnace, power house, wharf and ancillary installations on the northern side of the harbour, the five shipbuilding berths, together with the associated departments on its western extremity, a fitting-out wharf, 150-ton cantilever crane, fitting-out shop, and administrative building on its southern side. In addition to these installations, a brickmaking plant was built close by. Further developments occurred during and after the war. They included the erection of a forge shop, an electric steel melting shop and steel foundry, and a heavy machine and precision gear cutting shop. More recently, C. A. Parsons Australia, Ltd., built a plant in the same area, equipped initially to manufacture steam condensers and turbo-generators. This new plant is about 2 miles north of the township and is the most recent addition to Whyalla's growing number of industries. All these developments have had a marked impact not only on the growth of Whyalla, but on the State generally. In accommodating them, Whyalla has expanded to become South Australia's second largest town, outside Adelaide and one, moreover, which B.H.P. has been at pains to preserve as a model in its standard of housing and amenities. Since it was blown in in May, 1941, the blast-furnace has produeced more than 2,000,000 tons of pig iron, most of it of foundry grades, for the Australian ferrous foundry market. Twenty-five ships, in all a deadweight tonnage of 160,000 have been launched from the ship-yard since 1941. Their gross value amounts to more than £A15,000,000. Of these twenty-five ships, fifteen have been launched since the end of the war; they include the four largest ships yet to be built in Australia—bulk carriers of the "Yampi" class, for the ironstone trade, each of approximately 12,500 tons deadweight. Of the vessels built at Whyalla since 1941, seven to date have been for the iron and steel industry's own fleet. The remainder represent orders placed by the Royal Australian Navy and the Australian Shipbuilding Board, a Commonwealth agency. The seven vessels built by B.H.P. to augment its own fleet have cost £A9,000,000.

The Whyalla shipbuilding yard is thus playing a vital part in the industrial and economic life of Australia. Few countries depend as heavily on shipping as Australia, and a vigorous merchant marine is necessary to maintain the domestic economy in a healthy condition. For heavy industry, merchant shipping is particularly important, since it is the principal agent for moving raw materials to the processing centres and finished producst to interstate markets. Shipping is, in fact, the iron and steel industry's lifeline in that country. The need to have virile shipbuilding facilities is therefore obvious, and the Whyalla shipyard, although it has been built and maintained at considerable cost, is of vital importance to the nation. But for the serious shortage of manpower at Whyalla, it would be able to play an even more important part in helping to meet Australia's growing need of ships. As things are, it is possible to use only a fraction of the yard's building capacity, because of the labour shortage—skilled and unskilled—and until that problem is solved it will not be able to play the effective part that was planned for it. Even so, it has made an important contribution to Australia's post-war expansion.

The establishment of so large an industry at Whyalla was bound to stimulate development in other fields. In the wake of the shipyard came the electric steel melting shop and forge plants. Built, it is true, as defence measures during the war, they have performed valuable services to the iron and steel industry in the post-war period. The building and equipping of a heavy machine and precision gear cutting shop in recent years indicates the importance B.H.P. attaches to its manufacturing activities at Whyalla. The new shop is in many ways unique and the equipment already installed in it represents a substantial addition to the industrial capacity of the nation. Its wide range of gear cutting machines makes possible the carrying out of vital work, not only for the iron and steel industry's own expansion programme, but for other manufacturers, including marine engineers in Australia and for Commonwealth, Naval and defence authorities. With the establishment of the works of C. A. Parsons Australia, Ltd., a further step forward has been taken. In a word, the facilities for undertaking an ever-widening range of heavy industrial work at Whyalla are steadily being built up by the iron and steel industry itself and more recently by others. The momentum of industrialisation is there and will assuredly continue.

Impact of Post-War Expansion

The expansion of the iron and steel industty in South Australia has not been limited only to development at Whyalla and its hinterland during recent years. During the war a new source of

limestone flux to meet the needs of the industry's smelting operations was opened at Rapid Bay, 60 miles south of Adelaide, and in the course of the past fourteen years a new extractive industry and settlement have come into existence there. A fully mechanised quarry and loading jetty supply upwards of 500,000 tons of limestone a year to Whyalla, Port Kembla and Newcastle. More recently a similar kind of development has occurred at Ardrossan, on the east coast of Yorke Peninusla, where the iron and steel industry has developed a source of dolomite to meet the needs of its open-hearth steel furnaces. As at Rapid Bay, this development has brought a new extractive industry to South Australia. A quarry crushing station and steel mechanised loading jetty, projecting 3000ft out into St. Vincent's Gulf, have been established, and since 1951 Ardrossan has furnished on the average 65,000 tons of dolomite a year to the industry. The value to Yorke Peninsula of the new bulk-loading facilities has been heightened by their usefulness to the Australian Wheat Board, which utilises the installations to bulk-load wheat. A large grain storage bin has been built near the head of the jetty and barley as well as wheat is now being handled. Salt harvested on the peninsular is also loaded over the jetty. These installations have thus given a fillip to other activities on Yorke Peninsula, providing a useful point of export for some of its major bulk products.

Pyrites for the Manufacture of Sulphuric Acid

B.H.P. has been party in recent years to a development in South Australia, which, while not directly related to iron and steel smelting, will have considerable consequence for South Australia. It concerns the opening of the pyrites deposit at Nairne in the Adelaide hills, with a view to recovering a concentrate from which sulphuric acid and ultimately furtiliser can be manufactured. At the request of the South Australian Government, B.H.P. undertook in 1951 to join with three other companies to form Nairne Pyrites, Ltd., a company established to quarry and treat the pyrites to concentrate form. B.H.P. was asked to be the managing agent and during the past three years work has done forward steadily in opening the deposit at Nairne and erecting the crushing and concentrating plant. A stage has now been arrived at when pyrites concentrate is available for further treatment at Port Adelaide. B.H.P. has played a leading part in this project, which is planned to reduce South Australia's dependence on imported sulphur for the manufacture of sulphuric acid and the much-needed sulphate fertilisers. In undertaking the development, B.H.P. has brought to bear the knowledge and experience of its technical personnel in large scale quarrying, crushing and treatment works, acquired over many years of operation in those fields.

Developments in Western Australia

Western Australia possesses important raw material resources, but her industrial development has dragged behind the rest of the Continent. At the end of the second world war she was still producing more wheat, wool and gold then manufactured goods. Since then, however, there has been an intensive drive to develop new industries in an effort to broaden the basis of the local economy. The discovery of a limited quantity of oil—16,000 barrels were drawn in 1954 from the Western Australian Petroleum Company's wells at Rough Range—has encouraged further borings. But the three major developments have been the construction of an oil refinery and a steel rolling mill at Kwinana, 13 miles south of Fremantle, in Cockburn Sound, and the opening up of new high-grade iron ore deposits in Yampi Sound, 85 miles north of Derby. Australian consumption of petroleum products increased to nearly 6,000,000 tons in 1954 and the Kwinana refinery, built by Australian Petroleum Refinery, Ltd., at a cost of £40,000,000, is one of four new refineries built since the war which, when in full operation, will make Australia entirely independent of imported petroleum products. Cockburn Sound provides an excellent deep water harbour though it has been necessary to deepen the approaches to it by dredging to facilitate the passage of tankers.

With the development of a source of iron ore in Western Australia, the question again arose of the possibility of using the ore within the borders of the State. The main difficulty is the lack of good metallurgical coking coal, for although the State possesses large coal reserves at Collie in the south-west, no economic method has yet been devised for using them in iron and steel production. The Government, however, developed a blast-furnace, using charcoal as fuel, which turns out about 11,000 tons annually of good quality pig iron. Later in 1952, after discussions between the Government and the Broken Hill Proprietary Company, it was decided that the company should built a rolling mill at Kwinana capable of turning out a wide range of merchant steel sections, as the most effective and economical contribution towards Western Australian industrialisation. Good progress has since been made and the mill should be completed and in operation early next year. Its installed capacity with existing furnace and with stands operating on a three-shift basis will be 50,000 tons of rolled steel a year. The mill has been designed to roll a wide variety of merchant steel sections, including bars, rounds, angles, squares and flats. It has been located close to the water's edge so as to have ready access to a new all-steel unloading jetty and to rail transport. Its main raw material will be billets shipped around from the primary rolling mills on the east coast. They will be unloaded at the jetty, which is serviced by a 10-ton luffing crane and stockpiled in a billet yard adjoining the mill. An oil-fired reheating furnace will bring the billets to appropriate rolling temperatures. The rolling mill has been designed in all important respects by B.H.P.'s engineers and consists of one 16in, three-high breakdown stand, four 13½in intermediate stands, and two 12in finishing stands. A fence post plant is already operating at Kwinana (using Y-bar rolled on the east coast), and has a capacity of 5000 tons of steel fence posts a year. Almost all the equipment for the mill has been built in Australia, a number of Western Australian firms having played an important part in the construction programme. The project has involved B.H.P. in an expenditure of nearly £A4,000,000.

A thorough investigation of Yampi Sound as a source of ironstone for the steel industry to supplement supplies from South Australia began in 1935 when the Australian Iron and Steel Ltd., who had acquired the lease, merged with the Broken Hill Priprietary Company. All preparatory work, however, was stopped by the war. It was not until the end of 1944 that it was possible to resume operations on Cockatoo Island, one of two islands on the north side of the Sound where large deposits of iron ore had been discovered in 1880. Cockatoo Island iron ore is of high metallic content and in substantial tonnage, but its remoteness from the iron and steel works on the East Coast of Australia imposes a considerable freight burden. To meet the need for suitable ships to transport the ore from Yampi Sound to the Newcastle Steel Works (2985 nautical miles) and the A.I.S. Kembla Works (3085 nautical miles), B.H.P. decided to design and build four 12,500 tons (deadweight) vessels at its Whyalla shipyard. The first ship of the "Yampi" class, the S.S. "Iron Yampi" (the largest ship then built in Australia), was launched in 1947, and, appropriately, this vessel had the distinction of being the first to load iron ore at the island in 1951. While the "Iron Yampi" was building, work went steadily on at Cockatoo Island. Provision was made for a settlement to care adequately for 250 or more people, including wives and children as well as the men themselves. In the design of housing particular provision was made for climatic conditions by adequate ventilation and sun protection. Refrigerators were installed in all dwellings which were also supplied with electric light and cooking equipment.

The Cockatoo Island ore body may be described as a single bed of hæmatite which outcrops for a length of about 7000ft and varies in width from about 15ft to 100ft. Underlying the hæmatite bed is a band of red, ferruginous schist which, for about 1000ft of its length, gives place to a soft, powdery hæmatite ore. The whole of the quarrying, crushing and shiploading equipment is electrically operated. Electric shovels of 4 cubic yards capacity, caterpillar mounted, load the broken ore blasted down from the face into 28-ton capacity diesel-engined, side-dumping trucks. These trucks deliver the ore to a primary jaw crusher 84in by 50in, driven by a 300 h.p. motor. The maximum size of a piece to be fed to the crusher is a 4ft cube weighing 8 to 10 tons. From the primary crusher the ore, now of 12in maximum size, passes to a surge bin of 500 tons capacity. From this bin the ore is fed to two secondary jaw crushers, each 36in by 24in, and driven by a 125 h.p. motor. A belt conveyor 42in wide transfers the crushed ore to a storage bin with a capacity of 20,000 tons. From this bin a belt conveyor 42in wide with a shuttle and hinged boom at the offshore end loads direct into the ships' hatches. The power plant is housed in a steel-framed building 108ft by 65ft; equipment installed includes three 750 h.p. diesel engines, each driving a 400kW alternator generating at 3000V. In addition, one 250kW house set is provided.

On the historic first voyage the "Iron Yampi" left Newcastle on July 11, 1951, and arrived at Cockatoo Island on July 21st, steaming on the northern route through Torres Strait.

Books of Reference

Electrical Engineer's Reference Book. Edited by E. Molloy and M. G. Say, Ph.D., M.Sc., M.I.E.E. George Newnes, Ltd., Tower House, Southampton Street, London, W.C.2. Eighth edition. Price 70s.—Among the new articles in the eighth edition of this reference book is one on nuclear power for electricity generation: it outlines the principles of nuclear reactors and the British and foreign nuclear power programmes. The section on power station practice is now brought up to date by the introduction of an article on gas turbine power plants. A new article on silicones is included in the section on materials, and the article on copper, contains new matter. Certain gaps that existed in the text of previous editions are filled by the inclusion of articles on metal rectifiers, earthing and rotating amplifiers, including the Amplidyne, Metadyne, Magnicon and Magnavolt. Other parts of the book have been revised in accordance with statutory and other changes. For example, the information about transmission distribution and supply now takes account of the new structure of the Central Electricity Authority arising out of the Electricity Reorganisation (Scotland) Act, 1955; similarly, the articles on motors are in accord with the new B.S. 2613 : 1955. Likewise, note is taken of the thirteenth edition, 1955, of the I.E.E. Regulations for the electrical equipment of buildings. A perusal of these and other sections of the book (including the one dealing with progress, research and development) suggests that the text has been revised with thoroughness befitting a reliable book of reference.

International Symposium of Non-Destructive Testing of Materials and Structures. Réunion Internationale des Laboratoires D'Essais et de Recherches sur les Matériaux et les Constructions (RILEM). Paris: 12, Rue Brancion (15e). In English or French. Two volumes. Price 2000 francs (members 1400 francs), postage 200 francs.—The present work embodies the texts of the papers read before the International RILEM Symposium on Non-Destructive Tests of Concrete, held in Paris in January, 1954. These methods of measurement already currently applied in the field make possible a precise analysis of the mechanical characteristics and the physical properties of concrete in place and enable one to detect the defects, cracks, frost effects, patching of faulty concreting. They revolutionise the testing techniques of concrete structures, the testing of which up to the present was virtually limited to the conventional crushing of cubes, whose defects and inaccuracies are well known.

The non-destructive tests call for three kinds of measurements, viz. the measurement of the speed of sound in the concrete, the measurement of the rebound of a metal ball on the surface of the concrete, and measurements using γ radiation from radioactive isotopes.

Results obtained by researchers in nineteen countries will be found in this document. Of particular interest are the different laws proposed for linking the mechanical characteristics determined by these tests to the compressive resistance that is given by the test on cubes, and is quoted in the specifications. The text of the discussions that followed the reading of the papers on each of the three methods enumerated above is also given.